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New Interpretation of the Recent Result of AMS-02 and Multi-component Decaying Dark Matters with non-Abelian Discrete Flavor Symmetry

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Abstract

We propose a new interpretation of the recent result of the AMS-02 experiment, that Dark Matter (DM) can be two component because it shows flash damp at around 125 GeV of the positron energy. One of interpretations of that is primary source from annihilation into charged leptons of multi-component DMs. It is important to fix the flavor of final states in this case. This is achieved by imposing non-Abelian discrete symmetry as same as deriving the proper neutrino mixing. By assuming two gauge-singlet fermionic decaying DMs, we show that a model with non-Abelian discrete flavor symmetry, *e.g.* T_{13}, can successfully explain the damp of the positron fraction as well as the whole-range data. Few dimension six operators of universal leptonic decay of DMs are allowed in our model, since its decay operators are constrained by the T_{13} symmetry. We also show that the lepton masses and mixings are consistent with current experimental data, due to the flavor symmetry.

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1 Introduction

The latest experiment of Planck [1] tells us that about 26.8 % of energy density of the universe consists of Dark Matter (DM). On the other hand, recent result of the indirect detection experiment of AMS-02 [2] is in favor of the previous experiments such as PAMELA [3] and Fermi-LAT [4], which reported excess of positron fraction in the cosmic ray. Moreover, it smoothly extends the anomaly line of positron fraction with energies up to about 350 GeV[1]. Along this line of thought, several papers have been released [6–13]. However, since AMS-02 as well as Fermi-LAT has also shown a flash damp of the line at around 125 GeV, that might imply an existence of lighter DM at this range if its damp has truly physical meaning[2].

In this paper, we show that this damp as well as the whole-range data can be explained by two-component fermionic decaying DMs. We introduce two pieces of decaying DMs (with mass of $\mathcal{O}(10^2)$ GeV and $\mathcal{O}(1)$ TeV) into the framework of T_{13} flavor symmetric scenario [15]. In our model, the flavor symmetry T_{13} works (at least) in two ways: (i)It constrains interactions between DMs and the Standard Model(SM) particles. Since DMs (gauge singlet fermion X and X') couple with leptons by dimension six operators $\bar{L}E\bar{L}X^{(\prime)}/\Lambda^2$ due to the T_{13} symmetry, these are leptophilic. DMs decay into leptons via these operators with the suppression factor $\Lambda \sim 10^{16}$ GeV, giving desired lifetime of DMs, $\Gamma^{-1} \sim ((\mathrm{TeV})^5/\Lambda^4)^{-1} \sim 10^{26}$ sec [16, 17]. (ii)Flavor of the final states of DM decay is determined by the T_{13} symmetry. In this paper, we give a concrete example of the universal final states $DM \to \nu_e e^+ e^- / \nu_\mu \mu^+ \mu^- / \nu_\tau \tau^+ \tau^-$.

The lighter DM is applied to explain the flash damp at around 125 GeV. The heavier one is, on the other hand, done to depict the main anomaly line up to 350 GeV that suggests the mass being larger than 700 GeV. Due to a specific selection rule by the flavor symmetry mentioned above, we show that two-component DM model is preferable for explanation of the AMS-02 result. In addition to that, we find a set of parameters that is consistent with the observed lepton masses and their mixings (especially rather large angle of θ_{13}) recently reported by several experiments [18–24].

This paper is organized as follows. In the next section, we briefly mention the group theory of T_{13} and show the multiplication rules. After that, we construct mass matrices of the lepton sector in definite choice of T_{13} assignment of the fields, and show that there exists a consistent set of parameters. In section 3, we show that desirable dimension six DM decay operators are allowed by T_{13} symmetry and that leptonic decay of the two DMs by those operators shows good agreement

[1] These observations can be, in general, explained by scattering and/or decay of the GeV/TeV-scale DM particles. Still leptophilic DM is preferable since PAMELA measured negative results for anti-proton excess [5].

[2] This damp also occurs in the experiment of cosmic-ray proton and Helium spectra [14].

	n	h	$\chi_{\mathbf{1_0}}$	$\chi_{\mathbf{1_1}}$	$\chi_{\mathbf{1_2}}$	$\chi_{\mathbf{3_1}}$	$\chi_{\mathbf{\bar{3}_1}}$	$\chi_{\mathbf{3_2}}$	$\chi_{\mathbf{\bar{3}_2}}$
$C_1^{(0)}$	1	1	1	1	1	3	3	3	3
$C_{13}^{(1)}$	13	3	1	ω	ω^2	0	0	0	0
$C_{13}^{(2)}$	13	3	1	ω^2	ω	0	0	0	0
C_{3_1}	3	13	1	1	1	ξ_1	$\bar{\xi}_1$	ξ_2	$\bar{\xi}_2$
$C_{\bar{3}_1}$	3	13	1	1	1	$\bar{\xi}_1$	ξ_1	$\bar{\xi}_2$	ξ_2
C_{3_2}	3	13	1	1	1	ξ_2	$\bar{\xi}_2$	ξ_1	$\bar{\xi}_1$
$C_{\bar{3}_2}$	3	13	1	1	1	$\bar{\xi}_2$	ξ_2	$\bar{\xi}_1$	ξ_1

Table 1: Characters of T_{13}. $\bar{\xi}_i$ is defined as the complex conjugate of ξ_i.

with the cosmic-ray anomaly experiments. Section 4 is devoted to the conclusions.

2 Lepton masses and mixings with T_{13} flavor symmetry

First of all, we briefly review the non-Abelian discrete group T_{13}, which is isomorphic to $Z_{13} \rtimes Z_3$ [15, 25–27]. The T_{13} group is a subgroup of $SU(3)$, and known as the minimal non-Abelian discrete group having two complex triplets as the irreducible representations. We denote the generators of Z_{13} and Z_3 by a and b, respectively. They satisfy $a^{13} = 1$ and $ab = ba^9$. Using them, all of T_{13} elements are written as $g = b^m a^n$, with $m = 0, 1, 2$ and $n = 0, 1, \cdots, 12$.

The generators, a and b, are represented *e.g.* as

$$b = \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{pmatrix}, \quad a = \begin{pmatrix} \rho & 0 & 0 \\ 0 & \rho^3 & 0 \\ 0 & 0 & \rho^9 \end{pmatrix}, \text{ where } \rho = e^{2i\pi/13}. \tag{2.1}$$

These elements are classified into seven conjugacy classes, and T_{13} has three singlets $\mathbf{1}_k$ with $k = 0,\ 1,\ 2$ and two complex triplets $\mathbf{3_1}$ and $\mathbf{3_2}$ as irreducible representations. The characters are shown in Table 1, where $\xi_1 \equiv \rho + \rho^3 + \rho^9$, $\xi_2 \equiv \rho^2 + \rho^5 + \rho^6$, and $\omega \equiv e^{2i\pi/3}$. The multiplication rules

of the T_{13} group are shown as

$$
\begin{aligned}
\mathbf{3_1}\otimes\mathbf{3_1} &= \bar{\mathbf{3}}_\mathbf{1}\oplus\bar{\mathbf{3}}_\mathbf{1}\oplus\mathbf{3_2},\ \bar{\mathbf{3}}_\mathbf{1}\otimes\bar{\mathbf{3}}_\mathbf{1}=\mathbf{3_1}\oplus\mathbf{3_1}\oplus\bar{\mathbf{3}}_\mathbf{2},\\
\mathbf{3_2}\otimes\mathbf{3_2} &= \bar{\mathbf{3}}_\mathbf{2}\oplus\bar{\mathbf{3}}_\mathbf{2}\oplus\bar{\mathbf{3}}_\mathbf{1},\ \bar{\mathbf{3}}_\mathbf{2}\otimes\bar{\mathbf{3}}_\mathbf{2}=\mathbf{3_2}\oplus\mathbf{3_2}\oplus\mathbf{3_1},\\
\mathbf{3_1}\otimes\mathbf{3_2} &= \mathbf{3_2}\oplus\bar{\mathbf{3}}_\mathbf{2}\oplus\mathbf{3_1},\ \mathbf{3_1}\otimes\bar{\mathbf{3}}_\mathbf{2}=\bar{\mathbf{3}}_\mathbf{1}\oplus\bar{\mathbf{3}}_\mathbf{2}\oplus\mathbf{3_1},\\
\mathbf{3_2}\otimes\bar{\mathbf{3}}_\mathbf{1} &= \mathbf{3_1}\oplus\bar{\mathbf{3}}_\mathbf{1}\oplus\mathbf{3_2},\ \bar{\mathbf{3}}_\mathbf{1}\otimes\bar{\mathbf{3}}_\mathbf{2}=\bar{\mathbf{3}}_\mathbf{1}\oplus\bar{\mathbf{3}}_\mathbf{2}\oplus\mathbf{3_2},\\
\mathbf{3_1}\otimes\bar{\mathbf{3}}_\mathbf{1} &= \sum_{k=0,1,2}\mathbf{1}_k\oplus\mathbf{3_2}\oplus\bar{\mathbf{3}}_\mathbf{2},\\
\mathbf{3_2}\otimes\bar{\mathbf{3}}_\mathbf{2} &= \sum_{k=0,1,2}\mathbf{1}_k\oplus\mathbf{3_1}\oplus\bar{\mathbf{3}}_\mathbf{1}.
\end{aligned}
\tag{2.2}
$$

The tensor products between singlets are found as $\mathbf{1}_0\otimes\mathbf{1}_0=\mathbf{1}_1\otimes\mathbf{1}_2=\mathbf{1}_0,\ \mathbf{1}_1\otimes\mathbf{1}_1=\mathbf{1}_2,\ \mathbf{1}_2\otimes\mathbf{1}_2=\mathbf{1}_1$. The tensor products between triplets and singlets do not have an affect on their property.

Let us move on discussion the lepton masses and mixings in the setup shown in Table 2. Here, Q, U, D, L, E, $H(H')$ and $X(X')$ denote left-handed quarks, right-handed up-type quarks, right-handed down-type quarks, left-handed leptons, right-handed charged leptons, Higgs bosons, and gauge singlet fermions, respectively[3]. Here notice that X and X' is Majorana- and Dirac-type DM, respectively. Due to the T_{13} flavor symmetry in addition to an appropriate choice of the additional Z_3 symmetry, triplet Higgs bosons $H(\mathbf{3_1})$ and $H(\bar{\mathbf{3}}_\mathbf{2})$ couple only to leptons, while T_{13} singlet Higgs bosons $H'(\mathbf{1_{0,1,2}})$ couple only to quarks. Therefore, the mass matrices of quark sector are not constrained, while those of lepton sector are determined by the T_{13} symmetry. For the neutrino sector, since the Yukawa couplings $LHX^{(\prime)}$ are forbidden by the T_{13} symmetry, the left-handed Majorana neutrino mass terms are derived from dimension five operators $LHLH$. Here notice that $X(X')$ has dimension six operators $\bar{L}E\bar{L}X^{(\prime)}$ and mass terms. For the matter content and the T_{13} assignment given in Table 2, the charged-lepton and neutrino masses are generated from the T_{13} invariant operators

$$
\begin{aligned}
\mathcal{L}_Y &= \sqrt{2}a_e\bar{E}LH^c(\bar{\mathbf{3}}_\mathbf{2})+\sqrt{2}b_e\bar{E}LH^c(\mathbf{3_1})\\
&+ \frac{a_\nu}{\Lambda}LH(\bar{\mathbf{3}}_\mathbf{2})LH(\bar{\mathbf{3}}_\mathbf{2})+\frac{b_\nu}{\Lambda}LH(\bar{\mathbf{3}}_\mathbf{2})LH(\mathbf{3_1})\\
&+ \frac{c_\nu}{\Lambda}LH(\bar{\mathbf{3}}_\mathbf{2})LH(\mathbf{3_1})+h.c.,
\end{aligned}
\tag{2.3}
$$

where $H^c=\epsilon H^*$ and the fundamental scale $\Lambda=10^{11}$ GeV (For the lifetime of DM, $\Lambda/\sqrt{\lambda}\sim 10^{16}$ GeV is required to obtain the desired lifetime, where λ is coupling constant of DM decay operators).

[3]All the assignment and particle contents are the same as our previous work [15] except the DM sector.

	Q	U	D	L	E	H	H'	X	X'
$SU(2)_L \times U(1)_Y$	$\mathbf{2}_{1/6}$	$\mathbf{1}_{2/3}$	$\mathbf{1}_{-1/3}$	$\mathbf{2}_{-1/2}$	$\mathbf{1}_{-1}$	$\mathbf{2}_{1/2}$	$\mathbf{2}_{1/2}$	$\mathbf{1}_0$	$\mathbf{1}_0$
T_{13}	$\mathbf{1_{0,1,2}}$	$\mathbf{1_{0,1,2}}$	$\mathbf{1_{0,1,2}}$	$\mathbf{3_1}$	$\mathbf{3_2}$	$\mathbf{3_1}, \mathbf{\bar{3}_2}$	$\mathbf{1_{0,1,2}}$	$\mathbf{1_0}$	$\mathbf{1_1}$
Z_3	1	ω	ω^2	1	1	1	ω	1	1

Table 2: The T_{13} and Z_3 charge assignment of the SM fields and the Majorana DM X and the Dirac DM X', where $\omega = e^{2i\pi/3}$.

After the electroweak symmetry breaking, the Lagrangian Eq.(2.3) gives rise to mass matrices of charged leptons M_e and neutrinos M_ν

$$M_e = \begin{pmatrix} 0 & b_e v_1 & a_e \bar{v}_2 \\ a_e \bar{v}_3 & 0 & b_e v_2 \\ b_e v_3 & a_e \bar{v}_1 & 0 \end{pmatrix}, \tag{2.4}$$

$$M_\nu = \frac{1}{\Lambda} \begin{pmatrix} c_\nu \bar{v}_3 v_2 & a_\nu \bar{v}_1^2 + b_\nu \bar{v}_3 v_1 & a_\nu \bar{v}_3^2 + b_\nu \bar{v}_2 v_3 \\ a_\nu \bar{v}_1^2 + b_\nu \bar{v}_3 v_1 & c_\nu \bar{v}_1 v_3 & a_\nu \bar{v}_2^2 + b_\nu \bar{v}_1 v_2 \\ a_\nu \bar{v}_3^2 + b_\nu \bar{v}_2 v_3 & a_\nu \bar{v}_2^2 + b_\nu \bar{v}_1 v_2 & c_\nu \bar{v}_2 v_1 \end{pmatrix}, \tag{2.5}$$

where the vacuum expectation values (VEVs) of the Higgs bosons are defined as

$$\langle H(\mathbf{3_1})^i \rangle = \frac{v_i}{\sqrt{2}}, \ \langle H(\mathbf{\bar{3}_2})^i \rangle = \frac{\bar{v}_i}{\sqrt{2}}, \ \sum_{i=1}^{3} \left(v_i^2 + \bar{v}_i^2 \right) = (246 \text{ GeV})^2. \tag{2.6}$$

Now we give a numerical example. By the following choice of parameters

$$\begin{aligned} v_1 &= 4.269 \text{ GeV}, \ v_2 = 161.1 \text{ GeV}, \ v_3 = 78.62 \text{ GeV}, \\ \bar{v}_1 &= 10 \text{ GeV}, \ \bar{v}_2 = 168.2 \text{ GeV}, \ \bar{v}_3 = 0.04836 \text{ GeV}, \\ a_e &= 0.01057, \ b_e = 0, \ a_\nu = -8.220 \times 10^{-5}, \\ b_\nu &= 8.439 \times 10^{-5}, \ c_\nu = 3.632 \times 10^{-3}, \end{aligned} \tag{2.7}$$

the mass matrices Eqs. (2.4) and (2.5) give rise to mass eigenvalues and related observables as

$$
\begin{aligned}
m_e &= 0.511 \text{ MeV}, \ m_\mu = 105.7 \text{ MeV}, \\
m_\tau &= 1777 \text{ MeV}, \ m_{\nu 1} = 6.324 \times 10^{-3} \text{ eV}, \\
m_{\nu 2} &= 1.078 \times 10^{-2} \text{ eV}, \ m_{\nu 3} = 5.046 \times 10^{-2} \text{ eV}, \\
\Delta m^2_{21} &= m^2_{\nu 2} - m^2_{\nu 1} = 7.62 \times 10^{-5} \text{ eV}^2, \\
\Delta m^2_{32} &= m^2_{\nu 3} - m^2_{\nu 2} = 2.43 \times 10^{-3} \text{ eV}^2, \\
\langle m \rangle_{ee} &= 2.83 \times 10^{-4} \text{ eV}, \ \sum_i m_{\nu i} = 5.49 \times 10^{-2} \text{ eV},
\end{aligned} \tag{2.8}
$$

and the mixing matrices

$$
U_{eL} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}, \ U_{eR} = \begin{pmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}, \tag{2.9}
$$

$$
\begin{aligned}
U_{MNS} &= U^\dagger_{eL} U_\nu = \begin{pmatrix} 0.819 & 0.552 & -0.156 \\ -0.304 & 0.648 & 0.698 \\ -0.487 & 0.524 & -0.698 \end{pmatrix}, \\
\theta_{12} &= 34^o, \ \theta_{23} = -45^o, \ \theta_{13} = -9^o
\end{aligned} \tag{2.10}
$$

which are all consistent with the present experimental data [28, 29]. In particular in the case of $U_{eL} = 1$, the mass matrices Eqs. (2.4) and (2.5) require normal hierarchy $m_{\nu 1} < m_{\nu 2} < m_{\nu 3}$ of the neutrino masses and $U^{MNS}_{e3} \neq 0$. A comprehensive analyses of the T_{13} symmetric models have been done by several authors [30]. In the following analysis, we assume these parameters to discuss decaying DMs.

3 Decaying dark matter in the T_{13} model

It is well known that the cosmic-ray anomalies measured by AMS-02 [2], PAMELA [3] and Fermi-LAT [4] can be explained by DM decay with lifetime of $\Gamma^{-1} \sim 10^{26}$ sec. If the DM (X and X' in our case) decays into leptons by dimension six operators $\bar{L}E\bar{L}X^{(\prime)}/\Lambda^2$ and $\Lambda \sim 10^{16}$ GeV, such long lifetime can be achieved. In general, however, there exist several gauge invariant decay operators of lower dimensions: dimension four operators inducing too rapid DM decay, and dimension six operators including quarks, Higgs and gauge bosons in the final states, which must be forbidden in a successful model. By the field assignment of Table 2, most of all the decay operators listed

Dimensions	DM decay operators
4	$\bar{L}H^c X^{(\prime)}$
5	$-$
6	$\bar{L}E\bar{L}X^{(\prime)}$, $H^\dagger H\bar{L}H^c X^{(\prime)}$, $(H^c)^t D_\mu H^c \bar{E}\gamma^\mu X^{(\prime)}$,
	$\bar{Q}D\bar{L}X^{(\prime)}$, $\bar{U}Q\bar{L}X^{(\prime)}$, $\bar{L}D\bar{Q}X^{(\prime)}$, $\bar{U}\gamma_\mu D\bar{E}\gamma^\mu X^{(\prime)}$,
	$D^\mu H^c D_\mu \bar{L}X^{(\prime)}$, $D^\mu D_\mu H^c \bar{L}X^{(\prime)}$,
	$B_{\mu\nu}\bar{L}\sigma^{\mu\nu}H^c X^{(\prime)}$, $W^a_{\mu\nu}\bar{L}\sigma^{\mu\nu}\tau^a H^c X^{(\prime)}$

Table 3: The higher dimensional operators which cause decay of X and X' up to dimension six [31]. $B_{\mu\nu}$, $W^a_{\mu\nu}$, and D_μ are the field strength tensors of hypercharge gauge boson, weak gauge boson, and the electroweak covariant derivative.

in Table 3 [31] except for $\bar{L}E\bar{L}X^{(\prime)}$ are forbidden due to the T_{13} symmetry [4]. With the notation $L_i = (\nu_i, \ell_i) = (U_{eL})_{i\alpha}(\nu_\alpha, \ell_\alpha)$ and $E_i = (U_{eR})_{i\beta}E_\beta$ $(i = 1, 2, 3,\ \alpha, \beta = e, \mu, \tau)$, the four-Fermi decay interaction is explicitly written as

$$\begin{aligned}
\mathcal{L}_{\rm decay} &= \frac{\lambda_X}{\Lambda^2}\sum_{i=1}^{3}(\bar{L}_i E_i)\bar{L}_i X + (X \to X') + \text{h.c.} \\
&= \frac{\lambda_X}{\Lambda^2}\sum_{i=1}^{3}\left(\omega^{2(i-1)}\right)\sum_{\alpha,\beta,\gamma}(U_{eL})^*_{i\alpha}(U_{eR})_{i\beta}(U_{eL})^*_{i\gamma} \\
&\times \left[(\bar{\nu}_\alpha P_R E_\beta)\left(\bar{\ell}_\gamma P_R X\right) - \left(\bar{\ell}_\gamma P_R E_\beta\right)(\bar{\nu}_\alpha P_R X)\right] + (X \to X') + \text{h.c.},
\end{aligned} \tag{3.1}$$

where in the case of X' decay, the factor $\left(\omega^{2(i-1)}\right)$ has to be multiplied because of the multiplication rule of the T_{13} flavor symmetry. As seen from Eq. (3.1), decay mode of the DM particles $X(X')$ depends on the mixing matrices $U_{e(L,R)}$, which are given in Eq. (2.9).

Next, we consider the branching fraction of the DM decay through the T_{13} invariant Lagrangian Eq. (3.1). Due to the particular generation structure, the DM particles $X(X')$ decay into several tri-leptons final state with the mixing-dependent rate. The decay width of DM X per each flavor is defined as

$$\Gamma_{\alpha\beta\gamma} \equiv \Gamma(X \to \nu_\alpha \ell^+_\beta \ell^-_\gamma) + \Gamma(X \to \overline{\nu_\alpha}\ell^+_\beta \ell^-_\gamma), \tag{3.2}$$

[4]Notice that $H^\dagger H\bar{L}H^c X^{(\prime)}$ and $H^\dagger H X X'$ cannot be forbidden. Here we assume these couplings of these surviving terms to be enough tiny. However, we expect that these terms can be forbidden by modifying the other flavor symmetries with higher order elements such as $\Sigma(81)$ of $\Sigma(3N^3)$ [32], A_5 [33], the double covering of A_5 [17], and T_{19} of T_N.

and the decay width $\Gamma_{\alpha\beta\gamma}$ is calculated as

$$\Gamma_{\alpha\beta\gamma} = \frac{|\lambda_X|^2 m_X^5}{32\,(4\pi)^3\,\Lambda^4}\,(U_{\alpha\beta\gamma} + U_{\alpha\gamma\beta})\,, \tag{3.3}$$

where m_X is the DM mass, and

$$U_{\alpha\beta\gamma} = \left|\sum_{i=1}^{3}\left(\omega^{2(i-1)}\right)(U_{eL})^*_{i\alpha}\,(U_{eR})_{i\beta}\,(U_{eL})^*_{i\gamma}\right|^2. \tag{3.4}$$

The decay width of X' named $\Gamma'_{\alpha\beta\gamma}$ is obtained by replacing $X \to X'$. Note that the factor $\left(\omega^{2(i-1)}\right)$ is needed in the case of X' decay. The differential decay width is required to get energy distribution function $dN/dE_{e^\pm}$, and is expressed as

$$\frac{d\Gamma_{\alpha\beta\gamma}}{dx} = \frac{|\lambda_X|^2 m_X^5}{48\,(4\pi)^3\,\Lambda^4}x^2\Big((6-2x)U_{\alpha\beta\gamma} + (15-14x)\,U_{\alpha\gamma\beta}\Big) \tag{3.5}$$

where $x = 2E_{\ell_\beta^+}/m_X$. Here we have omitted the masses of charged leptons in the final states. In both X and X' DM cases, the flavor dependent factor $U_{\alpha\beta\gamma}$ gives a factor three if one takes the sum of flavor indices α, β and γ. Therefore, the branching fraction of each decay mode is given by

$$\mathrm{Br}(X \to \nu_\alpha \ell_\beta^+ \ell_\gamma^-) + \mathrm{Br}(X \to \overline{\nu_\alpha} \ell_\beta^+ \ell_\gamma^-) = \frac{1}{6}\,(U_{\alpha\beta\gamma} + U_{\alpha\gamma\beta})\,. \tag{3.6}$$

The DM mass m_X and the total decay width $\Gamma_X = \sum_{\alpha,\beta,\gamma}\Gamma_{\alpha\beta\gamma}$ are chosen to be free parameters in the following analysis. In the case of X', we can obtain it by replacing $X \to X'$.

Given the differential decay width and the branching ratios, the primary source term of the positron (electron) from DM decay at the position r of the halo associated with our galaxy is expressed as

$$Q(E,r) = n_X(r)\,\Gamma_X \sum_f \mathrm{Br}(X \to f)\left(\frac{dN_{e^\pm}}{dE}\right)_f + (X \to X')\,, \tag{3.7}$$

where $[dN_{e^\pm}/dE]_f$ is the energy distribution of positrons (electrons) from the decay of single DM with the final state f, and E is the energy of $e^\pm$. We use the PYTHIA [34] to evaluate the distribution function $[dN_{e^\pm}/dE]_f$. The non-relativistic DM number density $n_X(r)$ is written by $n_X(r) = \rho_X(r)/m_X$ with the DM profile $\rho(r)$. In this work, we adopt the Navarro-Frank-White (NFW) profile [35],

$$\rho_{\mathrm{NFW}}(r) \;=\; \rho_\odot \frac{r_\odot (r_\odot + r_c)^2}{r(r+r_c)^2}, \tag{3.8}$$

where $\rho_\odot \simeq 0.40$ GeV/cm^3 is the local halo density around the solar system, r is the distance from the galactic center whose special values $r_\odot \simeq 8.5$ kpc and $r_c \simeq 20$ kpc are the distance to the solar system and the core radius of the profile, respectively.

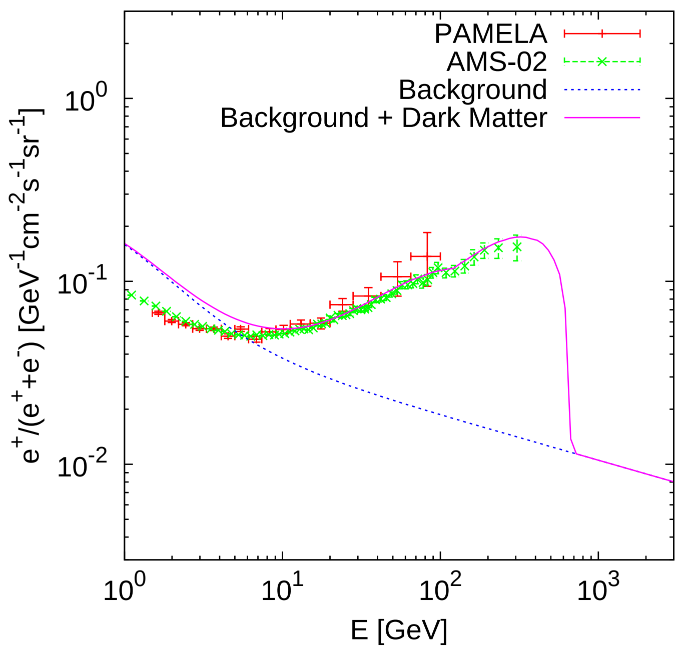

Figure 1: The positron fraction [2] and [3] predicted in the leptonically-decaying DM scenario with T_{13} symmetry. We fix the lighter DM mass to be m_X =244 GeV and the heavier DM mass to be $m_{X'}$ =1360 GeV. As for the DM decay width used in the fit, see the text.

As seen from Eqs. (2.9) and (3.3), the DM decays into $\tau^{\pm}$ as well as $e^{\pm}$ and $\mu^{\pm}$ in the equal rate. As a result, pure leptonic decays give dominant contributions, and it is consistent with no anti-proton excess of the PAMELA results [5]. We follow Ref. [16] for diffusion model describing the propagation of positrons and electrons [36–38], and backgrounds [36, 39].

Result for AMS-02 The positron fraction is depicted in Figure 1 for the scenario of the leptonically decaying DM with T_{13} symmetry. We can obtain the best fit point in terms of four parameters m_X, $m_{X'}$, Γ_X, $\Gamma_{X'}$ by χ^2-fit and the values are

$$m_X = 244 \text{ GeV}, \qquad \Gamma_X^{-1} = 1.2 \times 10^{28} \text{ s}, \tag{3.9}$$

$$m_{X'} = 1360 \text{ GeV}, \qquad \Gamma_{X'}^{-1} = 2.4 \times 10^{27} \text{ s}, \tag{3.10}$$

where we used 35 data of AMS-02 from higher energy. We obtain the value of $\chi^2 = 14.18$ (31 d.o.f) at the best fit point. In this figure, we fix to the acquired masses and decay widths, assuming that the number density between X and X' is the same. The result is shown with the experimental data of AMS-02 and PAMELA. One can see a small damp around $E \approx 125$ GeV. This is the result of multi-component DMs and the fixed flavor of final states by T_{13} symmetry. A sharper damp is

expected if we have larger branching ratio for directly produced positron.

4 Conclusions

We revisited a decaying DM model with a non-Abelian discrete symmetry T_{13}, and extended it to the two-component DM scenario by adding an extra DM X' in order to explain the flash damp of the anomaly line at around 125 GeV. We have shown that all the observed masses and mixings in the lepton sector are derived from the T_{13} model consistently. Due to also the specific selection rule of T_{13}, we have found that both of DMs have the universal decay coming from dimension six operators that gives a promising model in current indirect detection searches. In this paper, we have explicitly shown a numerical examples of a consistent set of parameters in the DM mass, their lifetime, and mass matrices of the lepton sector. We have found that the experimental small damp of AMS-02 can be explained by two-component DM scenario of m_X =244 GeV with $\Gamma_X^{-1} = 1.2 \times 10^{28}$ s and $m_{X'}$ =1360 GeV with $\Gamma_{X'}^{-1} = 2.4 \times 10^{27}$ s, assuming that X and X' have equal number density.

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